High Efficiency Engines and Turbines (HEET)

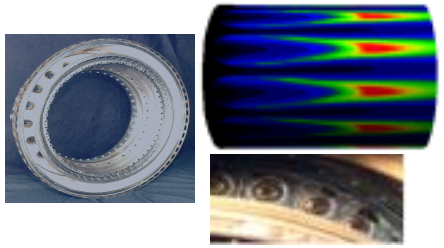
Abbie W. Layne
National Energy Technology Laboratory

ATS/HEET Comparisons

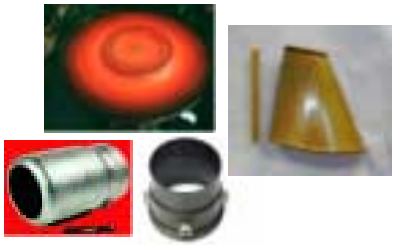
ATS-Product Development Focused

HEET-Technology Infusion Focused

Combustion



Materials & Structures



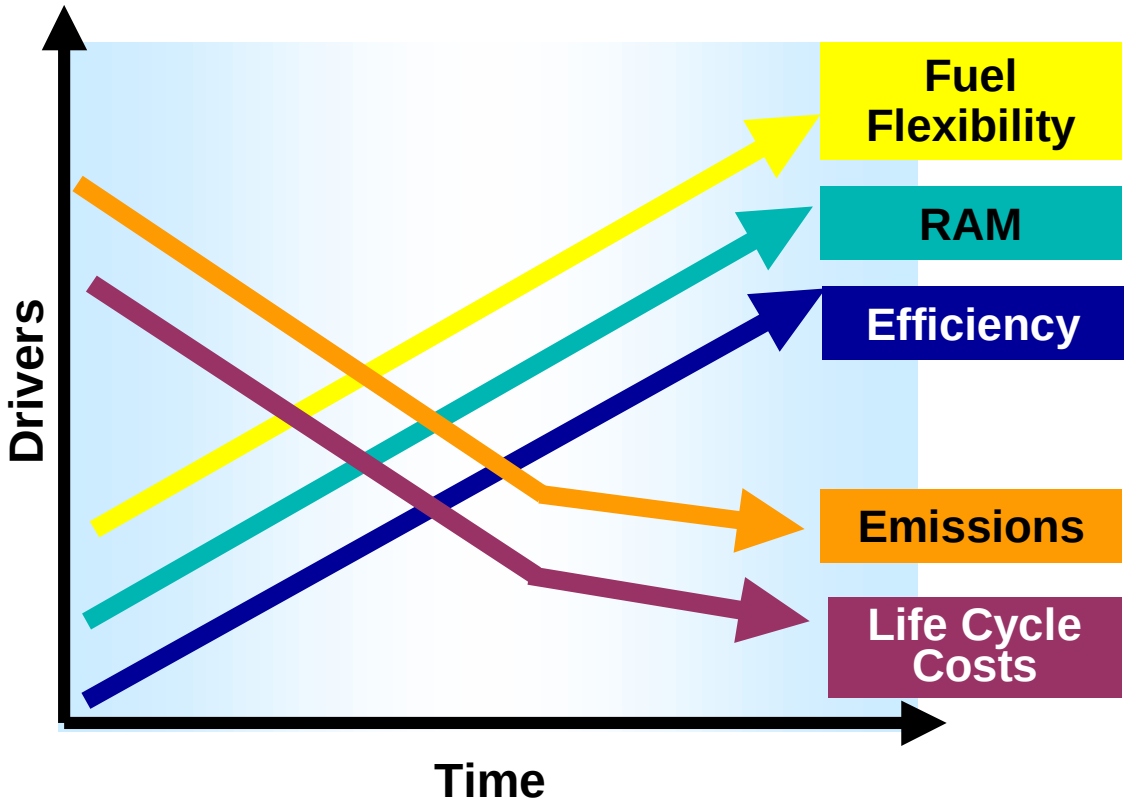
HEET Goals

By the year 2010…….

- **Conservation through reduced fuel use**
  - 60% electric efficiency(HHV) coal plants
- **Near zero emissions**
  - No carbon, negligible nitrogen oxide and trace contaminates
- **Flexibility - fuels/operational**
  - Coal syngas, hydrogen/at least 400 starts per year
- **Improved electricity reliability**
- **Competitive life cycle cost**

Drivers for Research Direction

Drivers



Technology Roadmaps

- **Materials**
  - alloys,ceramics
- **Combustion**
  - catalysts,rich/lean
- **Aero/Thermal**
  - inter-cooling,blade design
- **Condition Monitoring**
  - sensors,controls, diagnostics
- **Design Tools**
  - large eddy simulations

National Energy Policy Responsiveness

- **Chapter 2 and 4: Development of CHP**
  - For the near-term almost all turbine planned products are combined heat and power (CHP) and all are high efficiency (47-63%)

- **Chapter 5: Protect Environment with Clean Coal Technologies**
  - The fuel cell turbine hybrid technology is a key power block component of most high-efficiency, coal-based Vision 21 power plants

- **Chapter 8: Support New Technologies to Address Global Climate Change**
  - Because of their high efficiency and low CO2 and NOx emissions, turbines are ideal for any global climate change initiatives

HEET Development Plan

2003-2005

- 65% efficient hybrids(<40MW)
- 50% efficient coal turbine plants

2010

- 70% efficient hybrids(40MW)
- 55% efficient coal turbine plants

2015

- 75% efficient gas plants
- 60+% coal plants
- Propulsion

Pathways to Achieve Clean Coal Goals

Technology Roadmaps

- Materials
- Combustion
- Aero/thermal
- Controls/Sensors
- Condition Monitoring
- Design Tools

Advanced Power Plants

- Syngas/Hydrogen combined cycle
- Fuel cell/turbine hybrids
- Rocket engine steam cycle
- Ramjet engine
- Hydraulic compression

Technology roadmaps produce advanced coal fueled power plants

Public Benefits

- **Potential U.S. Market (year 2005-2015) - 160 GW**
- **Clean, reliable power in load congested regions**
- **By year 2020, cumulative savings*:**
  - Advanced Natural Gas Plants
    - Savings in the cost of electricity:$3.5 Billion/yr
    - Carbon emissions reduction: 30 Million tons/yr
  - Advanced Coal Plants
    - Savings in the cost of electricity: $350 Million/yr
    - Carbon emissions reduction: 15 Million tons/yr
- **Maintain U.S. industry competitive position in growing international power markets**
- **National solutions for power and defense -- Collaboration between agencies**

Planned Accomplishments -- FY 2002

Siemens - Westinghouse

501GS -- 60 Hz

501G Launch Site
Lakeland, Florida

375 MW, 59% Efficiency

Component Test	2002
Operation	2003

General Electric Company

7H -- 60 Hz(ATS)

2 x 107H Launch Site
Scriba, New York, USA

400 MW, 60% Efficiency

FSNL Test	2000
Wales 50Hz Operation	09/02
Scriba Operation	2004

Planned Accomplishments -- FY 2002
Materials and Ultra-Low Emissions

- **ORNL Single Crystal Welding:** Employ computational thermodynamics to investigate mechanisms for stray crystal formation in single crystal weld repairs
- **ANL NDE Technology for Oxide-Based Composites:** Evaluate NDE data as a function of fatigue test damage on oxide composites
- **ANL Ceramic Reliability:** Complete finite element stress distribution analysis of miniature specimen geometry
- **CFD Research:** Beta release of software for design of low-emission combustion systems
- **GE Advanced Combustion:** Evaluate sub-scale trapped vortex combustor
- **Solar Laser Stabilization:** CFD simulations will be used to determine the best laser focal positions for optimum flame stabilization and combustion oscillations abatement

Planned Accomplishments -- FY 2002

Improved Electricity Reliability

- **S-W TBC Monitor:** Infrared emission from TBCs and associated progressions of deterioration will be characterized
- **EPRI Life Management:** Coating oxidation damage will be estimated, creep damage predicted and maintenance intervals will be established and compared to OEM's formulas
- **EPRI Advanced Monitoring:** Turbine anomaly detection and diagnostic software module will be developed to correlate performance shifts with degradation issues
- **GE Smart Turbine:** Fabricate and test flame temperature sensor

Program Funding Profiles

DOE-Office of Fossil Energy

FY 2001 Appropriations	FY 2002 President's Budget	FY 2002 Congressional
$ 30.9 MM*	$0	$20.2MM
**$12.4-ATS* **$18.5-NGT*		

Non- DOE Collaborative Partners

DOD/NASA/DOE

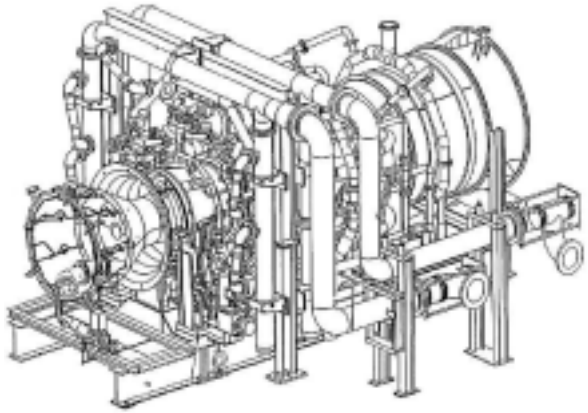
Turbine Engine Alliance

California Energy Commission - Public Energy Interest Research Program

Additional government collaborative partners planned

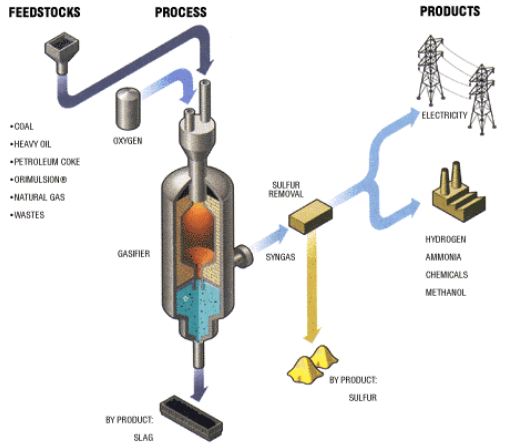
High Efficiency Engines and Turbines Road-Mapping Workshop

Results of the Reston, Virginia HEET Workshop



Reston, Virginia

February 7, 2002



Reston Roadmapping Summary

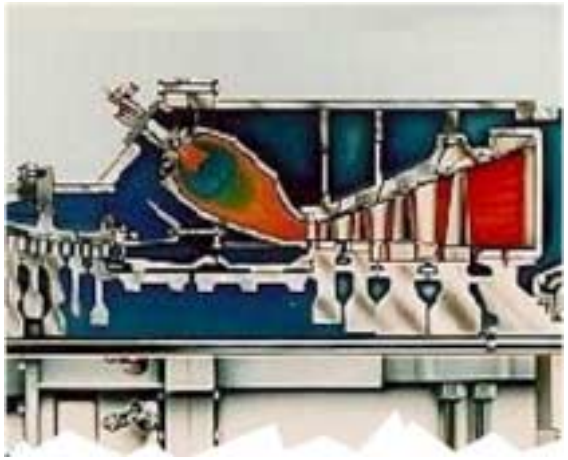
- **DOE and Gas Turbine Association sponsored a workshop in Reston, VA; February 7-8, 2002**
- **Focus was on industry recommendations for DOE sponsored R&D to support HEET Program**
- **Workshop yielded recommendations in three areas**
  - Policy
  - Program
  - Technology

HEET Road-Mapping Workshop-Speakers

- **Opening remarks-Joseph Strakey, Carl Bauer**
- **Presentations**
  - Jeff Abboud (GTA): National Energy Plan, bills pending in Congress to limit coal fired emissions
  - Abbie Layne (DOE): HEET Program Report to Congress, planned accomplishments, program goals, early entry demonstrations
  - Harvey Goldstein (Parsons): Market hurdles, commonality across roadmaps prepared by different organizations (DOE, EPRI, CURC, OEM's)

Performance and Emissions

- The next two slides show where we are and where we are going in terms of performance and emissions
- HEET activities must advance the state of the art to get us closer to meeting the program objectives. The devil is in the details.



Performance & Cost of Coal-Based & Gas- Based Systems

	Coal Fired Current PC	*Coal Fired HEET-IGCC*	*Gas Fired Current G/H Frame*	*Gas Fired HEET*
Efficiency	**39% hhv**	**60% hhv**	**60% lhv**	**75% lhv**
COE	**base**	**base-15%**	**base**	**base-15%**
Fuel Flexibility	**single type of coal**	**multi-fuel**	**nat gas or No. 2 oil**	**nat gas or syngas**
Reliability	**base**	**base +**	**base**	**base +**

Coal-Fired & Natural Gas-Fired Emissions

Current Systems:

Pollutant, lb/10^6 Btu	PC-Fired	NGCC
SO_2	0.12-0.35	Neg.
NOx	0.05-0.20	>0.03
CO_2	197-230	120-130
Particulate	0.001-0.010	Neg.

HEET Technology Based Systems: near zero emissions of SO2, NOx, Hg, particulates. Sequestration-ready for carbon management

Policy Recommendations

- Industry must have regulatory (*emissions*) certainty in order to risk capital developing new technologies
- Clean Coal Enterprise Zones and tax incentives
- National Materials/Combustion Test Facility recommended (Wilsonville?)
- Government (DOE) must fund in areas where industry will not where risk exceeds existing commercial incentives

Program Recommendations

- Determine realistic objectives for 2007
- Set mid-term goals with decision points and off-ramps
- Use distributed generation to demonstrate technology at a small scale
- Support cross-cutting technologies
- Encourage strategic partnerships *(Gov't/NGO's/industry/academia)*
- Evaluate fuel cycle to define infrastructure requirements

Technology Recommendations

- Develop better materials and coatings
- Test materials and combustors on syngas
- develop fuel-flexible, low emission, low acoustic combustors
- Develop better system simulation models and techniques, and do a better job with systems definition and integration
- Numerous other items that all contribute to an integrated program were suggested